Durability of femorofemoral bypass grafting after aortouniiliac endovascular aneurysm repair

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Introduction: **Endovascular aneurysm repair (EVAR) with aortouniiliac prostheses extends the morphologic range of aneurysms that can be treated and is potentially a more rapid and simple operation than bifurcated endovascular repair. It may, however, be limited by durability of the femorofemoral extra-anatomic bypass graft required to revascularize the contralateral lower limb. Previous studies of femorofemoral bypass grafts were performed almost exclusively in patients with occlusive disease. An 8-year single center experience with use of the femorofemoral bypass graft in aneurysmal disease is reported.**

Methods: **All patients undergoing EVAR with an aortouniiliac endovascular stent graft over eight years (1994-2002) at a single institution were included in a retrospective study. Patient data were collected from a prospectively maintained local endovascular database. All patients gave informed consent and were part of an endovascular program approved by the local ethics committee.**

Results: **Over the 8 years, 231 patients underwent EVAR with an aortouniiliac endovascular stent-graft. Median follow-up was 22 months. Localized wound complications were observed in 25 patients (11%). Cumulative 3-year patency rate for the femorofemoral bypass graft was 91%. At the end of 5 years 83% of grafts remained patent.**

Conclusions: **The femorofemoral bypass graft used during EVAR with aortouniliac stent grafts offers encouraging medium and long-term patency. When graft occlusion occurs, it is usually directly attributable to inadequate inflow from the endovascular stent graft itself or to endoluminal damage of the external iliac artery. Awareness and early detection of stent-graft distortion or complications in the external iliac artery may result in improved patency rates. (J Vasc Surg 2003;38:498-503.)**

The bifurcated configuration has gained popularity in endovascular management of abdominal aortic aneurysm (AAA) because it appears more anatomic than the uniiliac approach. Bifurcated stent grafts are, however, suitable in fewer patients and are more difficult and time-consuming to deploy.[1,2] An integral part of endovascular abdominal aortic aneurysm repair (EVAR) using an aortouniiliac endoprosthesis is the femorofemoral bypass graft. It has been argued that the additional extra-anatomic prosthetic bypass graft required for the uniiliac approach potentially increases the number of complications and limits durability of the aneurysm repair.

In occlusive arterial disease the patency of femorofemoral bypass grafts has proved inferior to that with aortobifemoral reconstruction.[3] However, early reports of the use of femorofemoral bypass grafts in aneurysmal disease have been more encouraging.[4] We report the medium and long-term durability of femorofemoral bypass after EVAR with aortouniiliac stent grafts.

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METHODS

All patients undergoing EVAR with aortouniiliac prostheses over 8 years (1994-2002) at a single institution were included in the study.

A variety of endovascular grafts were used, including the Chuter, Nottingham-Malmo, and Zenith (Cook Europe, Bjaerskov, Denmark). All endovascular stent grafts were manufactured of Dacron and supported by Gianturco stainless steel self-expandable stents. Details of these devices have been described.[5-7]

Aortouniiliac prostheses were used routinely from 1994 until 1998, with the exception of the early bifurcated Chuter prostheses. In 1998 a commercially produced bifurcated endograft (Zenith) became available for use in this institution. Since that time, all anatomically suitable patients have received bifurcated endoprostheses, with the exception of patients with ruptured aneurysm or adverse anatomy of one or both common iliac arteries (eg, length <35 mm; diameter >22 mm). The endograft was routinely deployed in the common iliac artery. When the common iliac artery did not present an adequate landing zone, principally in the presence of a common iliac artery aneurysm, or when thrombosis of a large internal iliac artery aneurysm was intended, an external iliac artery landing site was used.

Femorofemoral bypass grafting was standardized in all patients. Patients received a single intravenous dose of prophylactic antibiotics at induction of anesthesia, and were prepared with a chlorhexidene antiseptic solution. The anastomoses were made to the common femoral arter-

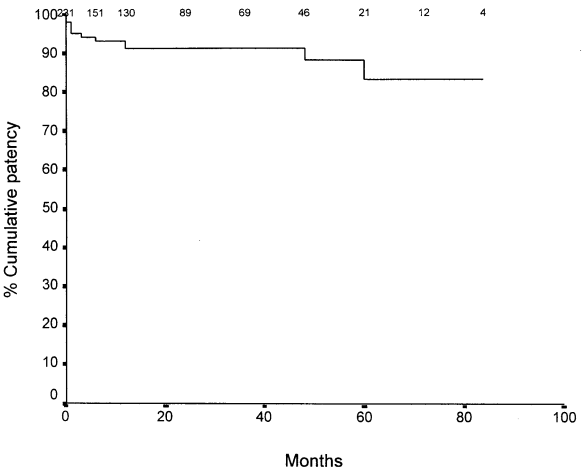
Table I. Life table analysis of femorofemoral bypass graft patency after EVAR with aortouniiliac stent

Interval (mo)	*No. of grafts at risk at start*	*No. of failed grafts*	*Loss to duration*	*Loss to follow-up*	*Loss to death*	*Interval patency rate*	*Cumulative patency rate (%)*	*Standard error (%)*
0-1	231	5	9	0	32	0.98	100	0
1-3	185	5	5	0	11	0.97	98	1.0
3-6	164	1	7	0	7	0.99	95	1.7
6-12	151	1	9	4	7	0.99	94	1.9
12-24	130	2	18	6	15	0.98	93	2.2
24-36	89	0	10	4	6	1.00	91	2.9
36-48	69	0	14	4	5	1.00	91	3.3
48-60	46	1	23	0	1	0.97	91	4.0
60-72	21	1	7	0	1	0.94	88	6.7
72-84	12	0	6	0	2	1.00	83	9.9
84-96	4	0	4	0	0	1.00	83	17.1

ies, and the graft was tunneled superficially, anterior to the rectus sheath. Two graft materials were used: polyester (Dacron) and polytetrafluoroethylene (PTFE), each of either 8 or 10 mm diameter. The type and diameter of graft varied according to surgeon preference and patient characteristics. Anticoagulation therapy was not routinely administered after graft insertion.

Preoperative, intraoperative, and perioperative data were collected prospectively for all patients and stored in a database. Superficial wound infection, seroma, and lymphocele were defined in an early report by our group.[4] Data are presented according to the guidelines suggested by the North American Society for Vascular Surgery for reports of lower extremity ischemia.[8]

After discharge, patients were entered in an EVAR surveillance program, which included clinical review and computed tomography of the abdominal aorta twice in the first postoperative year and yearly thereafter.



Kaplan-Meier analysis of femorofemoral graft patency.

RESULTS

Two hundred thirty-one patients underwent EVAR with aortouniiliac endografts. Two hundred seven of these patients were men. Mean age for the entire group was 72 years (range, 47-88 years). Median aneurysm diameter was 7.1 cm (range, 5.1-12 cm). Mean duration of follow-up was 29 months (median, 22 months). Sixty-nine patients were followed up for 3 years or longer. Overall perioperative mortality was 15% (n = 34). Cumulative patency rate was 91% at 3 years and 83% at 5 years (Table I; Figure).

Most crossover grafts (n = 170) were made of Dacron. Nineteen (8%) patients received 8-mm-diameter grafts; the remainder received 10-mm-diameter grafts. Mean duration of surgery was 165 ± 56 minutes (range, 60-540 minutes). However, duration of surgery was significantly longer in patients in whom graft infection subsequently developed compared with patients without graft infection ($P < .03$, Mann-Whitney U test; Table II).

Localized perioperative wound complications occurred in 25 patients (11%): groin hematoma in 9 patients (4%), seroma in 6 patients (3%), and superficial wound infection in 10 patients (4%). Graft sepsis developed in two patients developed after visceral damage incurred on tunneling the prosthetic graft. One of these patients had an unrecognized incisional hernia from previous laparotomy, and an enterocutaneous fistula subsequently developed. In the other patient serous fluid was discharged at tunneling of the prosthetic graft from one groin to the other. This patient had previously undergone laparotomy to treat intra-abdominal abscess.

Later infections were attributed to blood-borne infection. In one patient this was due to generalized abdominal sepsis after unrelated abdominal surgery performed many months later; in the other patients infection was suspected earlier in the postoperative course because of unexplained postoperative pyrexia, discharge from a groin wound, and formation of a wound sinus, which did not resolve despite a prolonged course of antibiotic therapy.

Graft infection was associated with high morbidity and mortality. Seven infected grafts required removal and implantation of another extra-anatomic bypass graft. Three patients were managed without operation, because of medical comorbidity in one patient, rendering that patient unfit for further surgical intervention, and presence of low-grade infection that responded to intermittent courses of antibi-

Table II. Comparison of patients with femorofemoral graft patency

	Total (n = 231)	*No complication (n = 211)*	*Occlusion (n = 10)*	*Infection (n = 10)*
POAD*	49	43	5	2
RAAA	30	29	0	1
Mean duration of operation (± SD)†	165 (56)	164 (57)	167 (39)	191 (45)
Diabetes mellitus*	9	6	1	3
Renal impairment	39	36	1	2
Graft material				
Dacron	170	158	6	6
PTFE	61	53	4	4
Graft material				
10 mm	212	192	11	9
8 mm	19	19	0	0

POAD, Peripheral artery occlusive disease; *RAAA*, ruptured abdominal aortic aneurysm; *PTFE*, polytetrafluoroethylene.
*One patient with occlusion and infection.
†Duration of operation longer in patients with subsequent graft infection ($P < .03$).

otic therapy in the others. Another 3 of the 10 patients with graft infection subsequently died of related complications. Limb salvage was attained in all patients who underwent secondary procedures (Table III).

Despite crossover graft sepsis, there was no clinical or radiologic evidence of direct or indirect contamination of the aortouniiliac prosthesis in any patient.

Of the 10 patients with femorofemoral bypass graft occlusion, 4 patients had symptomatic preexisting peripheral arterial occlusive disease (Table IV). None of these patients had critical ischemia. In all 10 patients with femorofemoral bypass occlusion there was coexisting occlusion of the endovascular aortic stent graft. The iliac limb of the endograft was deployed in the external iliac artery in 5 of the 10 patients with grafts that subsequently became occluded.

Of the other five patients in whom bypass grafts became occluded, four patients had an identifiable precipitating factor, ie, kinking of the main body or iliac limb of the endograft, resulting in poor femorofemoral bypass inflow. Two grafts occluded early, despite intraoperative treatment of kinks with a Wallstent, and two occluded later as a result of caudal migration of the endograft.

Restoration of graft patency was possible in only two patients. Both occlusions occurred early in the perioperative period and were managed with thrombectomy and insertion of Wallstents to straighten kinks in the endograft. Five patients received an extra-anatomic axillobifemoral bypass graft, and one patient underwent open aneurysm repair.

As a result of graft occlusion, there were two lower limb amputations and two deaths. Two patients were managed nonoperatively, one because of self-limiting claudication and the other because of advanced malignant disease.

DISCUSSION

The aortouniiliac configuration was adopted early in the evolution of endovascular aneurysm repair, because of the ability to load the stent graft onto a smaller sheath, combined with ease of manufacture. Subsequently uniiliac endografts were demonstrated to accommodate a greater number of aneurysms than either aortoaortic or bifurcated designs, principally because of their ability to exclude concomitant unilateral common iliac artery aneurysms.[1]

When the aortouniiliac system was first introduced, concerns were raised about durability of the extra-anatomic femorofemoral bypass. It was believed the additional graft would add to the morbidity of the procedure and adversely affect long-term outcome of the uniiliac configuration. Parallels were drawn with use of femorofemoral bypass grafting in iliac occlusive disease. In occlusive disease extra-anatomic bypass is generally accepted to carry a patency rate inferior to that with aortobifemoral reconstruction,[3] although some centers have reported 6-year patency rates in excess of 90% for femorofemoral bypass.[9]

However, early reports of femorofemoral bypass grafting in aneurysmal disease were encouraging, and suggested that femorofemoral bypass grafting in aneurysmal disease was associated with satisfactory patency rates and low morbidity. At a median follow-up of 7 months, the graft occlusion rate was 0.7%. In only 3% of patients was a secondary intervention required to treat a complication arising from the femorofemoral crossover graft.[4]

Local wound complications, eg, hematoma, seroma, and superficial wound infection, are not necessarily related to the femorofemoral bypass graft and can just as easily be related to dissection of the common femoral artery. Bifurcated devices may expect to produce in the region of 8.4% local groin complications, similar to the 11% experienced in our study.[10]

The potential for direct contamination and infection of the prosthetic graft is related to duration of operative procedure, and is likely to be greater with this configuration than with bifurcated devices. It is interesting that infection of femorofemoral bypass grafts has not been associated with direct or indirect spread of infection to the endovascular graft. Commonly reported 3-year patency rates for femorofemoral bypass grafting in occlusive disease range from 60% to 69%,[11,12] whereas the cumulative patency rate in the current study was 91% at 3 years and 83% at 5 years, which compares with the best outcomes reported for femorofemoral and aortobifemoral grafts.[3,9]

The results of this study suggest that patency of femorofemoral bypass grafting to treat aneurysmal disease is favorable when compared with occlusive disease. Similarly, aortobifemoral grafting is associated with a better prognosis when performed to treat aneurysmal disease compared with occlusive disease.[13] Indeed, it has been clearly demonstrated that early and late postoperative failure of both extra-anatomic and aortofemoral grafts is related to the presence of adequate runoff vessels.[14-16]

Table III. Demographic data for patients with femorofemoral graft infection

Patient	*Risk factor*	*Clinical presentation*	*Time after operation*	*Management*	*Outcome*
A	Laparotomy to treat unrelated abdominal sepsis	Perigraft collection and sepsis	71 mo	Graft removal and revision	Successful
B	Previous laparotomy because of unrelated abdominal sepsis; intraoperative Wallstent because of EVG occlusion	Localized groin sepsis	2 wk	Removal of femorofemoral bypass graft and insertion of axillo bifemoral bypass graft	Occlusion of one limb of axillobifemoral bypass graft
C	IDDM, groin hematoma	MRSA septicemia, graft dehiscence	2 wk	Graft excision and antibiotic-soaked graft inserted	Died of MI on day 30
D*	Heart failure, sepsis	Ischemic but viable lower limbs	1 mo	Axillobifemoral bypass graft	Perioperative death due to MI
E	Postoperative superficial groin wound infection	Early groin infection resolved with antibiotics; sinus subsequently developed	6 mo	Conservative; repeated courses of antibiotics, as necessary	Alive; graft patent at 42 mo
F	Ruptured AAA	Sepsis enterocutaneous fistula	1 wk	Laparotomy, repair of SB and revision of crossover graft	Perioperative death from multiple organ failure
G	Unexplained postoperative fever	Perigraft collection, pseudoaneurysm	23 mo	Graft revision to silver graft	Alive; graft patent at 32 mo
H	Unrecognised periampullary malignancy and low-grade DIC; secondary procedure to treat wound hematomas	Localized groin sepsis	2 wk	Conservative because of advanced malignancy	Died of disseminated malignancy (2 mo)
I*	Second procedure perioperatively to treat occlusion; BKA due to graft occlusion	Discharging wound sinus	23 mo	Conservative, antibiotics	Alive; graft patent at 15 mo
J	Long procedure requiring conversion from bifurcated to uniiliac EVG	Discharging wound	2 mo	Graft removed and replaced with extra-anatomic vein graft	Alive; graft patent at 9 mo

EVG, Endovascular graft; *IDDM,* insulin-dependent diabetes mellitus; *MRSA,* methicillin-resistant *Staphylococcus aureus*; *MI,* myocardial infarction; *SB,* small bowel; *DIC,* disseminated intravascular coagulation; *BKA,* below-knee amputation.
*Patient also included in Table IV.

There was no relationship between incidence of complications and type of graft material used, which corresponds to findings of a recent large prospective randomized study of Dacron and PTFE in aortofemoral bypass grafts.[17]

All femorofemoral bypass occlusion was associated with occlusion of the endovascular stent graft. In a report of the failure of endovascular aortic limbs, there appeared to be improved patency in aortouniiliac grafts (97%) at 18 months compared with bifurcated grafts (90%); however, the results did not reach statistical significance.[18] Rehring et al[19] reported a 98% primary patency rate over a similar time period (15.8 months) in patients with aortouniiliac endografts. Of interest, the one case of graft occlusion in the latter study occurred after iatrogenic dissection of the external iliac artery.

In a recent study of patients with unsupported endograft limbs, 24% developed endograft limb stenosis or occlusion during a mean follow-up of 16 months.[20] Fully stented endograft limbs appear to offer improved patency over unsupported limbs, probably related to their kink resistance.[18] However, the current range of fully stented designs remain at risk of kinking in tortuous arteries. The risk remains over the long term because of alterations in stent position secondary to migration or possibly longitudinal shrinkage of the aneurysm sac. Bifurcated endografts may be susceptible to occlusion of one iliac limb when both limbs compete for space in the presence of a narrow distal (waisted) aorta, which may compress one or other limb. Graft limb thrombosis was reported with bifurcated stent-graft systems: 7% at a mean of 11 months of follow-up by Stelter et al[21] and 5% at 7 months of follow-up by Faries et al.[10]

In the present study, inflow problems leading to early graft occlusion were due to either instrumentation damage of the external iliac artery, a low flow state created by an unrecognized kink in the endograft, or deployment of the endograft in a narrow external iliac artery.

Recent endograft designs have improved sheaths to try to reduce damage to the arterial intima. Deployment of endografts in narrow external iliac arteries should also be

Table IV. Demographic data for patients with femorofemoral graft occlusion

Patient	*Perioperative and postoperative risk factors*	*Clinical presentation*	*Time after operation*	*Management*	*Outcome*
1	Late EVG migration and kinking	Short-distance claudication	56 mo	Axillobifemoral bypass graft	Reocclusion required axillobifemoral bypass revision
2	Aorto-aortic EVG converted to AUI intraoperatively because of distal endoleak. Intra-op Wallstent for EVG angulation	Critical ischemia post-cholecystectomy	2 mo	Axillobifemoral bypass graft	Above-knee amputation
3	EVG deployed in right EIA (right CIA aneurysm); intraoperative Wallstent for EVG angulation; late EVG migration	Bilateral thigh claudication	15 mo	No intervention	Stable claudication
4	Intimal tear (dissection) of EIA	Critical ischemia	2 mo	Conversion to open repair	Successful reperfusion
5	PAOD (previous aortoiliac endarterectomy), inguinal lymphadenopathy (lymphoma), EVG deployed in EIA	Critical ischemia	2 wk	Insertion of Wallstents; CIA and EIA encased in tumor	Successful reperfusion
6	Carcinoma of unknown origin	Critical ischemia	9 mo	Conservative nonoperative treatment	Died of metastatic carcinoma, bronchus at 13 mo
7	PAOD, groin wound infection; EVG intentionally deployed in EIA, IIA occluded (CIA aneurysms); right EIA dissection	Short-distance claudication	2 mo	Axillobifemoral bypass graft	Successful reperfusion
8	Previous pelvic DXT; wound infection; EVG deployed intentionally in EIA	Critical ischemia	5 mo	Axillobifemoral bypass graft	Axillobifemoral occlusion; died
9*	PAOD, sepsis	Critical ischemia	1 mo	Axillobifemoral bypass graft	Perioperative death
10*	PAOD (claudication due to occluded popliteal aneurysms); right CFA aneurysm; EVG deployed intentionally in EIA to thrombose IIA aneurysm	Critical ischemia	2 d	Graft thrombectomy and Wallstent insertion	Below-knee amputation; late graft infection at 13 mo

EVG, Endovascular graft; *AUI,* aortouniiliac; EIA, external iliac artery; *CIA,* common iliac artery; *PAOD,* peripheral arterial occlusive disease; *IIA,* internal iliac artery; *CFA,* common femoral artery; *DXT,* radiotherapy.
*Patient also included in Table III.

averted, as suggested by Carroccio et al[22] in their study of bifurcated endografts. Occlusion of endografts extending into the external iliac arteries may be related to a number of factors, including gross oversizing of grafts, with inadequate deployment or crowding of graft material in the relatively narrow external iliac artery, low flow within a narrow external iliac artery, or kinking of the endograft at the angulation between the common and external iliac arteries.

Late occlusions were primarily associated with caudal migration and endograft kinking.

In the present study, occlusion of the femorofemoral bypass graft was associated with major morbidity. Of the eight patients treated at surgery, major amputation was required in two patients and another two patients died as a result of attempted revascularization. Lower limb salvage was possible in four of eight patients. In comparison with other studies of femorofemoral crossover occlusion, mortality appears high and is probably related to concomitant aortic occlusion, which occurred in the patients in this study, and associated medical comorbidity, for which many of these patients underwent endovascular procedures.

The studies of iliac limb occlusion in bifurcated endografts suggests that fewer patients present with critical ischemia, which may account for the improved outcome. In one study of bifurcated endograft limb occlusions only 8% of patients had rest pain, although 69% subsequently required some form of revascularization.[22] All revascularization procedures were successful in preventing limb loss, and there were no perioperative deaths. Improved outcome may also be related to preservation of collateral pathways via the iliac arteries. Indeed, three amputations were required in 22 patients (14%) undergoing femorofemoral

bypass grafting after conventional aortobifemoral graft limb occlusion.[23]

Endovascular management of graft occlusion may be a more attractive technique because of patient comorbidity, but was possible in only two patients. In both patients the technique was performed early in the postoperative period because of occlusion in association with endograft limb kinking. Graft patency was successfully restored in both patients, although amputation was required in one patient because of worsening of preexisting distal ischemia. Others have used endovascular techniques to good effect in management of iliac limb occlusion of bifurcated endovascular grafts, thus preventing the requirement for femorofemoral bypass grafting, although at the risk of limb separation in modular grafts.[24]

In conclusion, perioperative morbidity associated with aortouniiliac endovascular aneurysm repair and femorofemoral crossover is similar to that reported with bifurcated endovascular stent grafts.

Patency rate with femorofemoral bypass grafting is generally better than that reported for occlusive disease and comparable to that with open aortobifemoral or bifurcated endovascular repair of abdominal aortic aneurysm over the medium and long term.

In contrast to their use in iliac occlusive disease, the mode of graft failure appears to be related to problems of inflow rather than runoff. Specifically, patency of the femorofemoral bypass graft is ultimately related to performance of the aortouniiliac endograft.

Occlusion of the crossover graft may be prevented in the perioperative period with particular attention to avert damage to the donor external iliac artery or common femoral artery from arterial sheaths and guidewires, by preventing or treating kinking of iliac limbs, and by not deploying endografts in narrow external iliac arteries. Long-term patency is more likely to be assured with regular endograft surveillance to monitor stent-graft distortion.

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